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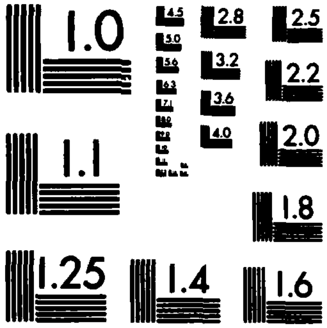

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PREDICTOR DISPLAYS AS TRAINING AIDS IN CARRIER LANDINGS

Dennis R. Weller
Human Factors Laboratory
Naval Training Equipment Center
Orlando, FL 32813

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This report presents an evaluation of the effectiveness of predictor displays as training aids in carrier landing. An experiment was performed in which two predictor displays were compared with a control condition, where the principal measure was total approaches necessary to reach criteron performance. Also evaluated were three presentation modes for the predictor displays. The experiment was carried out on a low-cost device which simulated an A-7 aircraft.

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20. Abstract (continued)

Analysis of the data indicated no significant differences between groups; although one predictor display consistently yielded better performance than the other conditions.

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SECTION I
INTRODUCTION

This report presents a brief summary of a research investigation into the use of predictor displays as training aids in carrier landing. A comprehensive report of this research is contained in Predictor Display Effectiveness for Carrier Landing Training by Wooldridge, Kovacs, and Weller. This present report summarizes the major points and conclusions of the earlier report, and excerpts from the earlier report will be included without further citation.

PREDICTOR DISPLAYS

A predictor display is one which shows, to the operator of a system, the predicted future state of the system. In this study, the system was a simulated aircraft and the operator was a pilot. Each future position of the aircraft was estimated using a computer model of the aircraft's dynamics. This model calculated the future position from information on the aircraft's current state and the current control inputs. The interval between the current state and the future position, known as the prediction span, was in the order of several seconds.

PREVIOUS RESEARCH

Previous research has shown that predictor displays improve the ability of operators to control vehicles such as aircraft, spacecraft, submarines, and ships. Several studies, using a variety of predictor displays, have demonstrated the effectiveness of these displays in improving aircraft landing performance in simulators (see e.g., Smith, Pence, Queen, and Wulfeck, 1974; Kennedy, Wulfeck, Prosin, and Burger, 1974). However, the training value of predictor displays has received very limited research attention.

CARRIER LANDING

Carrier landing is one of the most demanding tasks in aviation. During a carrier landing, rate of descent is controlled by engine power, and power adjustments are especially difficult due to the pronounced lag between throttle movements and the response of the engines. It has been suggested that pilots develop internal predictive models of the relationship between control inputs and aircraft responses as a way to allow for such lags.

It was reasoned that a display which could hasten the development of a pilot's internal predictive model might reduce the time required to learn the skill of carrier landing.

HYPOTHESIS

It was hypothesized that use of a predictor display in training would reduce the number of carrier approaches required to reach proficiency at the unaided carrier landing task. A secondary hypothesis was that a predictor display would reduce the error in glidepath tracking during carrier approaches.

SECTION II
PREDICTOR DISPLAY EXPERIMENTAL SYSTEM

Development of a system for the evaluation of predictor displays in carrier landing training required a detailed examination of prior research in predictor displays and an analysis of the specific requirements associated with the carrier landing task. This analytical study was documented in Lintern, Jensen, and Wooldridge (1979).

DISPLAY FORMATS

Some of the considerations in the development of a carrier landing predictor display are that the display elements must not interfere with the pilot's perception of the carrier, and that the pilot's normal pattern of scanning his instruments and the outside scene must not be unduly interrupted. Even with these restrictions, the number of possible predictor display formats is almost limitless. In designing the displays for this study, formats which were used successfully in previous studies were considered first. Practical limitations, such as the capabilities of available computer hardware and software, also influenced the choice of display formats. The three formats which were designed for this study are discussed in the following paragraphs.

SQUARE DISPLAY. The square display is shown in Figure 1. It consists of three squares, the centers of which fall on the proper glidepath; and three future position markers, which appear as crosses. The apparent distance from the aircraft to these elements is determined by the prediction span. The first (largest) square and cross appear as if they were ahead of the aircraft by a time equal to one prediction span, the intermediate square and cross appear at twice the prediction span, and the smallest square and cross appear at three times the prediction span. The effect is that of flying through a tunnel, where the center of the tunnel represents the proper glidepath and the three crosses represent the predicted path of the aircraft.

WING DISPLAY. The wing display is shown in Figure 2. It consists of five pairs of poles which begin at water level and extend vertically to the level of the proper glidepath, and three future position markers, or "wings". Similar to the square display, the wings are positioned ahead of the aircraft in proportion to the prediction span. The pilot attempts to fly so that the aircraft is centered between the two rows of poles, and the wings are just touching the tops of the poles.

GLIDELINE DISPLAY. The glideline display is shown in Figure 3. It consists of a line beginning at the carrier which represents the proper glidepath and a future position marker which is a small square. The square and the end point of the line appear as if they were one prediction span ahead of the aircraft. The pilot attempts to fly down the visible glideline, with the square centered upon it.

PRESENTATION MODE

The manner in which the predictor displays were presented during training was a potential factor in both skill acquisition and transfer effectiveness. Several schemes were possible, but three presentation modes were selected as appropriate for this study.

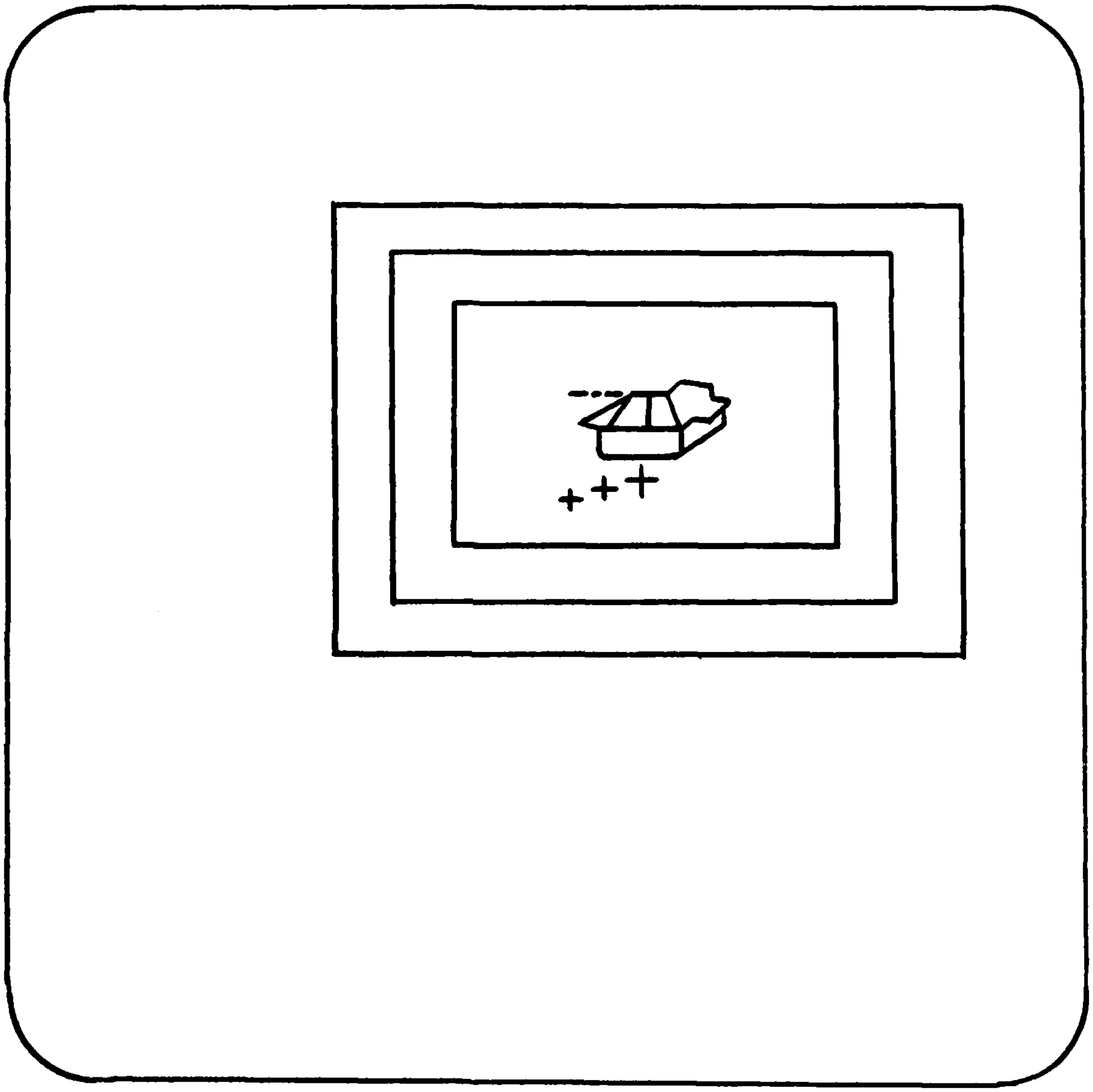


FIGURE 1. SQUARE PREDICTOR DISPLAY

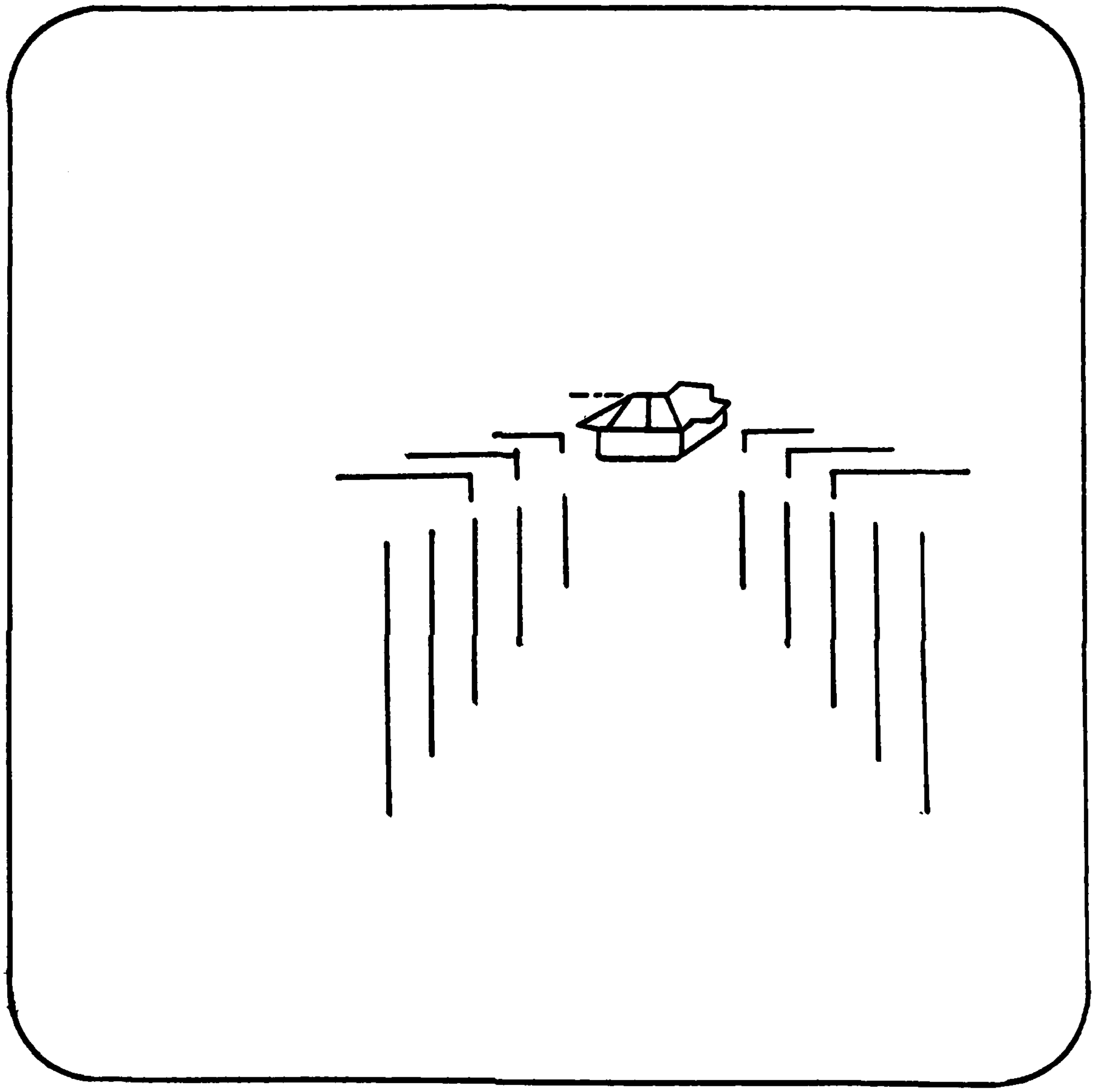


FIGURE 2. WING PREDICTOR DISPLAY

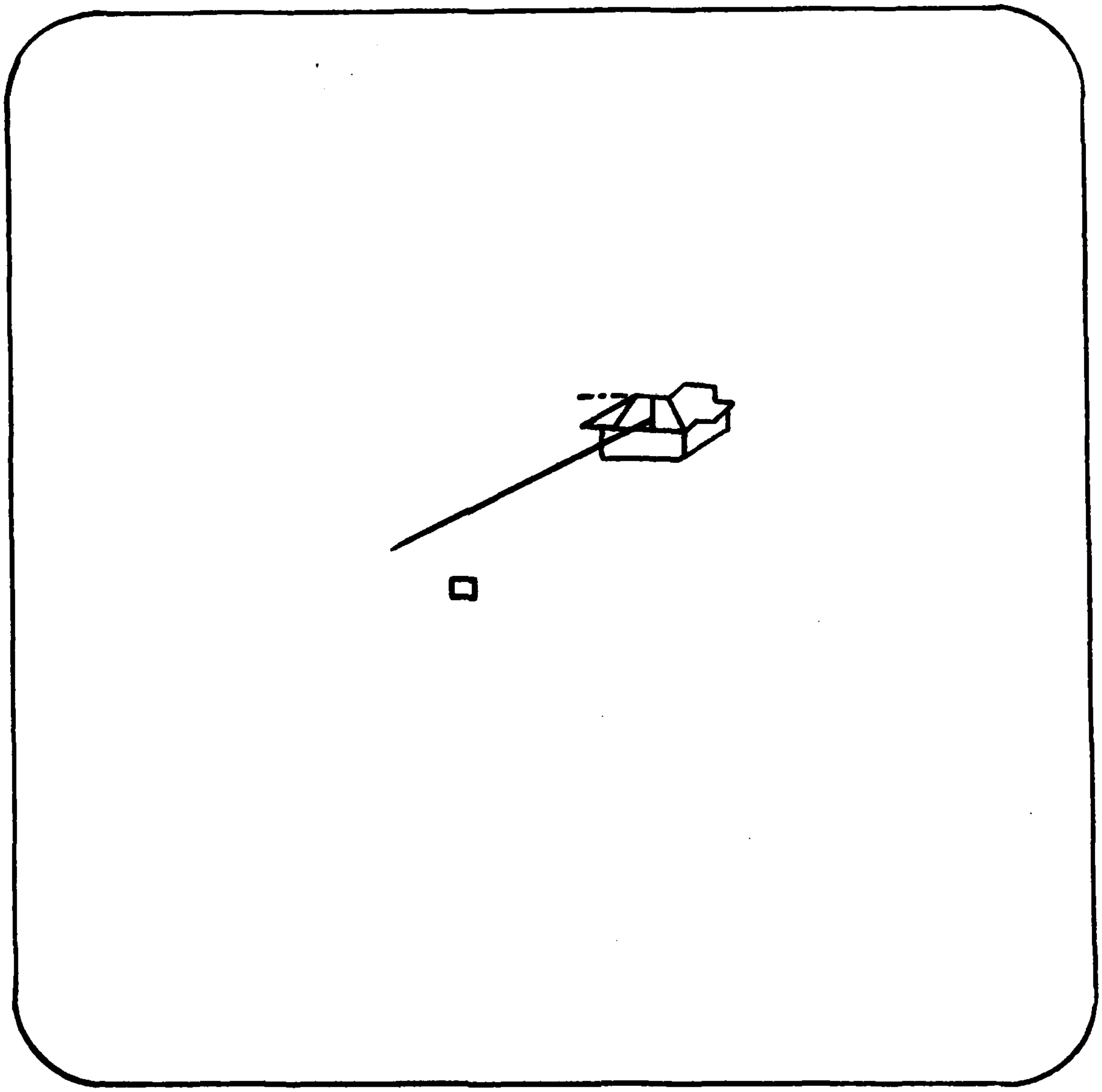


FIGURE 3. GLIDELINE PREDICTOR DISPLAY

CONSTANT MODE. In the constant presentation mode, the predictor display was present throughout all training approaches.

ADAPTIVE MODE. In the adaptive mode, the predictor display was only present when the aircraft was outside a tolerance band around the proper glidepath. The tolerance for lateral error was set at plus or minus 5 degrees, and the tolerance for vertical error was set at plus .75 degrees or minus .375 degrees from the proper glideslope. Less error was allowed below the glideslope because of the more serious consequences of a low approach.

PRESCHEDULED MODE. In the prescheduled mode, a specific schedule for presentation of the predictor display was determined in advance. In this case, the predictor was presented for two consecutive trials out of every four. This mode, and the adaptive mode, were designed to reduce the pilot's dependence on the augmentation during training.

SYSTEM HARDWARE AND SOFTWARE

The basic hardware system and aircraft model were not developed specifically for this study; but were adapted from an existing system.

HARDWARE. The system hardware included a PDP-11/34 computer with 28K of memory, a 13" diagonal calligraphic video display, a control stick, and a throttle. The equipment was contained in a standard 22" by 72" computer rack, with the display, stick, and throttle mounted in the appropriate locations for use by a seated person. The aircraft modelled by the system was an A-7 attack aircraft. The video display presented an "out of the window" view and a simulated instrument panel. The "out of the window" view included the carrier and one of the three predictor displays when appropriate. The FLOLS (Fresnel Lens Optical Landing System), which is the operational carrier landing aid, was also represented. The instruments shown were the altimeter, vertical velocity indicator, airspeed indicator, power indicator, and angle of attack indicator.

PREDICTOR ALGORITHM. The purpose of a predictor algorithm is to determine the future position of the aircraft. The algorithm is based on knowledge of the aircraft's dynamics, information on current control positions, and assumptions about control inputs which might occur during the prediction span. This last factor is necessary because it is unreasonable to assume that current control inputs will be held throughout the entire prediction span, which may be several seconds. It was assumed in this study that the stick would be returned to the neutral position in one second.

PERFORMANCE MEASUREMENT. An extensive set of variables was automatically collected for the measurement of pilot performance. These variables included information on all control positions, and measures of aircraft position, motion and orientation.

RESEARCH APPROACH

The independent variables in this study were predictor display format, presentation mode and prediction span. The three formats (square, wing, glideline) and the three modes (constant, adaptive, prescheduled) were all treated as separate experimental factors, since they did not fall along any describable continuum. Three values were selected for prediction span (2, 4,

and 6 seconds) based on previous experimental evidence.

The most comprehensive experimental design would have been a 3x3x3 factorial training design with 27 cells and one control group (the no predictor case). To pursue the full 28 cell experiment would have been beyond the scope of this study in terms of the number of subjects and the data collection time. In order to make the study more manageable, it was decided to perform two smaller experiments. The first of these experiments studied display format and prediction span, and the second studied display format and presentation mode.

SECTION III
PREDICTION SPAN STUDY

The principal purpose of this first study was to determine the appropriate prediction span to be used with each display format. The data gathered also allowed some comparisons to be made concerning the relative effectiveness of the three formats.

SUBJECTS

The subjects for this study were six male civilian pilots. Their average age was 38.6, and they averaged 526.5 hours of flight experience.

PROCEDURE

Five different starting positions were used for the carrier approaches; centered on glidepath, port-high, port-low, starboard-high, and starboard-low. Each subject flew all combinations of the four display formats (three predictor plus carrier only), three predictor spans, and five starting positions. The sixty possible conditions were presented in random order. A total of 240 trials were flown by each subject, which represents four approaches under each combination of conditions.

RESULTS

The numerous performance variables were combined into a single measure using canonical regression. The effects of prediction span on this measure were found to be negligible. The two, four, and six second spans produced essentially equivalent results. The effects of display format on landing performance were small and non-significant, but greater than the effects of span; with the wings and glideline formats superior to the square format and control conditions. Starting position had a greater effect than span or format although it was still non-significant. Initial offsets to starboard produced the best performance; and offsets to port produced the worst performance.

CONCLUSIONS

Since prediction span was found to have a negligible effect on landing performance, it was decided to use the average value, four seconds, for the following study.

The data indicated that the square display resulted in somewhat poorer performance than the other two predictor formats. Also, informal comments from some subjects indicated that they found the square display distracting. In the interest of applying available resources to the most promising conditions, it was decided to drop the square display from the following study.

SECTION IV
PRESENTATION LOGIC
AND
DISPLAY TYPE STUDY

The purpose of this study was to examine the relative training effectiveness of the two predictor displays and the three presentation modes.

PROCEDURE

EXPERIMENTAL CONDITIONS. This experiment involved six treatment groups and one control group. The treatment groups consisted of all combinations of the two predictor displays (wings and glideline) and the three presentation modes (constant, adaptive and prescheduled). All predictor displays used a four-second prediction span. The control group used no predictor display.

SUBJECTS. Civilian pilots were used as subjects for this study. Eight subjects were assigned to each of the seven conditions. For the most part, the subjects were male, relatively young, and had relatively low flight experience. These characteristics were consistent with most student naval aviators. Due to a limited subject pool, however, it was necessary to include one female and one highly experienced subject in each group in order to achieve a sufficient group size. The performance of the female and experienced subjects was found to be within the range of the other subjects. Subjects were assigned to groups with an effort to equalize demographic variables across groups, especially age and flight experience. The average age for all subjects was 27.3, and the average number of previous flight hours was 290.7.

PRE-TESTS. Two pre-tests were administered to all subjects. The first was the Embedded Figures Test, in which the subject must locate simple geometric figures which are embedded within more complex figures. It was felt that performance on this test might be related to the ability to integrate the type of symbology used in this experiment.

In the second pre-test, the subjects flew six simple flight maneuvers on the predictor display system, without the carrier view and without any predictor displays. The horizon and instruments were used to maintain control during these maneuvers.

ADMINISTRATION OF TREATMENTS. Following administration of pre-tests, carrier approach training began. Each subject flew approaches using the display and presentation mode appropriate to his/her condition until a criterion of four consecutive successful landings was reached. Following this, the subject flew unaided approaches (without predictor displays). These transfer trials continued until the subject had made four consecutive landings and had flown at least ten approaches.

RESULTS

TRIALS TO CRITERION. Table 1 presents averages of training trials, transfer trials, and total trials for each group. Analysis of variance determined that none of the group differences seen in this table are significant. Keeping this lack of statistical significance in mind, some interesting patterns appear in the data.

Considering both training trials and total trials, four of the experimental groups performed better than the control group; the glideline adaptive and glideline prescheduled groups did worse. Comparing across displays, the wings display was superior to the glidepath display. Comparing across presentation modes, the constant mode was superior to the other two. The wings/constant group showed the best performance of the seven groups.

Transfer trials showed a different pattern. All experimental groups performed better than the control group. The wings and glideline displays were roughly equivalent. The prescheduled mode was superior to the other two modes, and the glideline/prescheduled group performed the best of the seven groups. The variability in transfer trials was much smaller than that for training trials.

TABLE 1. TRIALS TO TRAINING AND TRANSFER

	DISPLAY					
PRESENTATION MODE	WINGS			GLIDELINE		
	Train	Transfer	Total	Train	Transfer	Total
Constant	51.2	33.4	84.6	63.9	35.1	99.0
Adaptive	66.5	35.2	101.7	94.0	32.1	126.1
Prescheduled	69.3	24.2	93.5	107.5	20.5	128.0

CONTROL NO PREDICTOR		
Train	Transfer	Total
75.2	39.2	114.4

GLIDESLOPE AND GLIDEPATH ERROR. Figures 4 and 5 present the results in terms of vertical and horizontal error from the glidepath. The data were averaged over blocks of five trials during training and transfer. Due to the differences among subjects in the number of trials completed, only the first three blocks were computed for training, and only the first and last blocks were computed for transfer. None of the differences between displays and presentation modes depicted in these figures was statistically significant.

Figure 4 shows the glideslope (vertical) error for each of the displays, averaged over the whole approach. In training, the wings display group performed best (least error). In transfer, the control group performed best initially, but the wings group improved by the last block to equal the control group.

Figure 5 presents data on glidepath (horizontal) error for the three displays over the whole approach. In training, the control group exhibited better performance initially, but the wings display group performed best in later stages. In transfer, the wings display group performed best.

Plots of error data for the three modes of presentation (not shown) showed no apparent advantage for any mode.

Taken as a whole, the graphical data indicates consistently better results with the wings display.

CORRELATIONAL DATA. Multivariate regression analysis was used to investigate the relationships between landing performance and other categories of data. Results of this analysis are presented in Table 2.

TABLE 2. VARIANCE IN LANDING PERFORMANCE* ACCOUNTED FOR (R^2) BY VARIOUS MEASURES

MEASURE	R^2
Flight Maneuver Pre-Test	.398
Background Questionnaire	.280
Embedded Figures Test	.274
Experimental Conditions	.164
ALL MEASURES	.834

*Landing performance measured by total trials to train and transfer.

FIGURE 4. GLIDESLOPE (VERTICAL) ERROR - WHOLE APPROACH

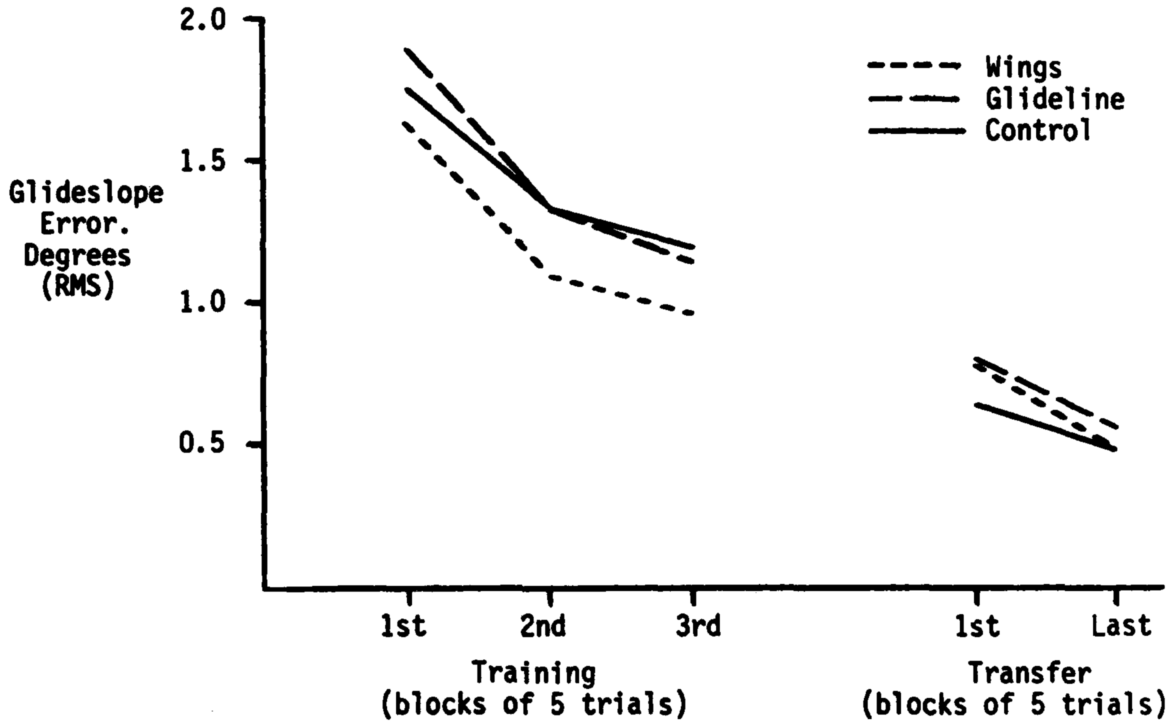
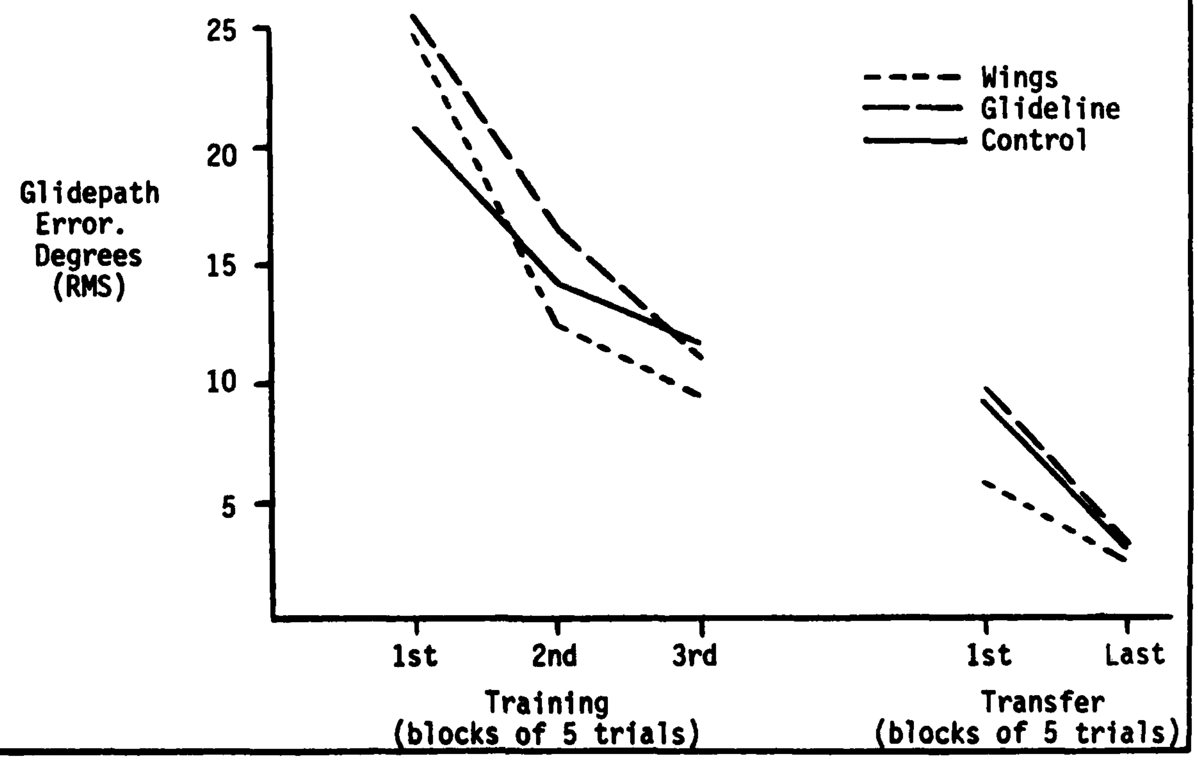


FIGURE 5. GLIDEPATH (HORIZONTAL) ERROR - WHOLE APPROACH



As shown in Table 2, it was possible to account for 83% of the variance in landing performance. Experimental conditions accounted for only 16%, while the various a priori measures accounted for the remainder. In other words, the particular display/mode combination used in training had less influence on landing performance than did the subject's background and pretest measures. The relationship between background measures and performance was expected. Of particular interest were the Embedded Figures Test and the Flight Maneuvers pre-test. These are both relatively brief tests which, taken together, account for over half of the variance in landing performance.

CONCLUSIONS. The principal purpose of this study was to evaluate the effectiveness of predictor displays as training aids in carrier landing training. As seen in the preceding results section, no statistically significant differences were obtained between performance with predictor displays and performance without them, either during training or transfer. However, some interesting patterns can be seen in the results. Across two different measures of performance (trials to criterion and glideslope and glidepath error) the wings display was consistently better than the glideline or control displays. As far as presentation modes were concerned, the constant mode was generally superior to the other two, although this result was not as consistent as that for display type. The wings/constant combination was consistently superior to the other conditions.

Prior research on the use of predictor displays in aircraft control tasks has generally yielded more significant results than those found in this study. A major difference between this study and previous studies is the use of the FLOLS landing aid. Each subject in this study had the FLOLS available on each approach and was briefed to attend to it as well as the predictor displays. This was necessary, since the criterion task was landing with the assistance of the FLOLS. The experimental comparisons were therefore not between groups using a landing aid and a group with no landing aid; rather the comparisons were between groups using two landing aids (FLOLS and predictor) and a group using only one (FLOLS). The presence of the FLOLS could easily have attenuated any effects of the predictor displays.

An important result from an operational point of view is the significant relationship between landing performance and certain a priori measures, notably the Embedded Figures test and the simple flight maneuvers. These results can benefit aviator selection through cognitive and task sampling techniques.

Although none of the main effects in this study were statistically significant, the consistent trends appearing in the data may warrant further investigation. Study could be limited to the most promisinj condition (wings/constant), and the Embedded Figures Test and simple flight maneuvers could be used as subject matching variables, thereby reducing within-group variance and improving the likelihood of finding statistical significance.

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